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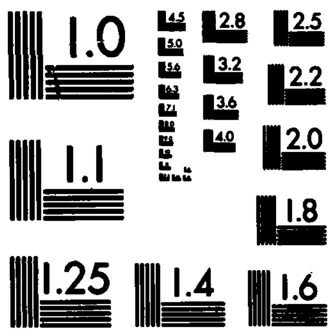

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What People Know About Electronic Devices: A Descriptive Study

David E. Kieras
University of Arizona

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Electronic devices, schemas, expert knowledge.

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consists of the major categories of what the device is for, how it is used, its structure in terms of subdevices, its physical layout, how it works, and its behavior. A preliminary theoretical framework for device knowledge is that it consists of a hierarchy of schemas, corresponding to a hierarchial decomposition of the device into subdevices, with each level containing the major categories of information.

Abstract

This report presents some informal descriptive results on the nature of peoples' natural knowledge of electronic devices. In the first study, expert and non-expert subjects were given an electronic device to examine and describe orally. The devices ranged from familiar everyday devices, to those familiar only to the expert, to unusual devices unfamiliar even to an expert. In the second study, college students were asked to describe everyday devices from memory. The results suggest that device knowledge consists of the major categories of what the device is for, how it is used, its structure in terms of subdevices, its physical layout, how it works, and its behavior. A preliminary theoretical framework for device knowledge is that it consists of a hierarchy of schemas, corresponding to a hierarchial decomposition of the device into subdevices, with each level containing the major categories of information.

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A

What People Know about Electronic Devices:

A Descriptive Study

David E. Kieras

University of Arizona

In our technological society people are often called upon to interact with devices or pieces of equipment. Especially prominent at this time are interactions with electronic or computerized equipment. It is a commonly-held belief that the instruction manuals and other documentation that accompany these devices are defective (see Bond & Towne, Note 1); we have all experienced the frustration of trying to assemble or operate an unfamiliar device from a set of incomplete or confusing instructions.

In terms of the current areas of study in cognitive psychology, the problem of operating a device from written instructions would seem to be a combination of two other areas of study, namely, the study of the acquisition of procedural knowledge, and the study of reading comprehension. However, there is another aspect to this situation which has had very little study. A person interacting with a device is attempting to manipulate the behavior of a separate system that might have internal states and complex rules of behavior that are either unknown, or only poorly understood, to the person operating the device. This makes the device operation situation rather different in kind from other procedural knowledge situations such as arithmetic learning, in which there is not an external interacting system that is distinct from the learner.

The fact that the device is a relatively independent system from the learner means that there is potentially a large variety of relevant knowledge that one needs to know about the system, in addition to the strictly procedural knowledge of how to operate it. As proposed by Kieras and Polson (Note 2), knowledge of devices can be very complex, spanning all the way from simple *layout knowledge* of where the buttons and controls on the device are, to *how-it-works knowledge* of the internal comprehension. Especially important is the knowledge of *how to use* the device. However, the bulk of the current work in cognitive psychology related to devices is focussed on the highly controversial topic of so-called "mental models" of systems.

But in the midst of all this discussion and controversy lies the problem that an adequate empirical characterization of what it means to know about a device is lacking. Likewise, before an adequate analysis can be made of the cognitive processes involved in comprehending operating instructions, we must have an adequate characterization of just what it is that one is expected to acquire from reading a set of instructions. The few studies that have been made of memory for procedures suggests very strongly that supplying information beyond the simple step-by-step procedures can be very important. Examples are the work by Smith (Note 3), who showed that providing very simple organizing information in an assembly task facilitated execution and memory for the specific assembly steps. In work in progress by Kieras and others, similar effects appear for instructions on operating pieces of electronic equipment. However, an adequate analysis of such effects requires an adequate description of what knowledge of the device can consist of.

This report contains some results on what ordinary people and electronics experts know about electronic devices, both everyday and unusual. The basic idea behind these studies is that device knowledge can be classified into a small number of basic categories, and that a valuable way to characterize this knowledge is in terms of the concept of a _schema_. A schema is supposed to be a familiar, frequently occurring, configuration of elements, organized in such a way that the person can use the schema to quickly recognize or categorize an object encountered in the environment, and make use of this information to predict what aspects or features this object will have, so that interactions with the object will proceed quickly and rapidly.

The schema concept has been developed most heavily in the context of story comprehension, where a schema consists of a familiar configuration of story elements, such as those making up episodes (e. g. Kintsch, 1977; Mandler, 1978, Haberlandt, Berian, & Sandson, 1980). However, since knowledge of devices consists of several different kinds of information, a device schema should also contain not only information that allows a familiar device to be recognized and "understood", but also to interact with the device. Thus, if device knowledge follows a schema organization, the person should not only be able to use the schema to recognize a device or predict its features, but also to predict its operating procedures, and to learn these procedures more readily. This report presents evidence that people have their natural knowledge about devices organized in schemas, and these schemas include both the schematic perceptual features of devices and schematic operating procedures as well. Due to the exploratory nature of the results and the small sample sizes, the statistical treatment of the results is purely descriptive. Future work can rely on these results to design more precise experiments.

EXPERIMENT 1

The first experiment was concerned with obtaining some descriptions of devices from both expert and naive subjects. The subjects described the device with the device actually present, and were free to manipulate the controls of the device, but the device was not actually in operation. By having people describe devices that were actually present, it was possible to gain some information on how people viewed novel devices. These very unconstrained descriptions could be used to answer three basic questions:

The first question was simply what kinds of information people produced for devices. The first experiment assumed a fairly simple classification of device knowledge. These kinds of knowledge can be listed as follows:

What it's for. A person can know what the function of a device is. More specifically, every device has been constructed with some user goals in mind that the device can be used to satisfy.

How to operate it. This is knowledge of the operating procedures for the device, which consists of sequences of steps for interacting with the device in order to fulfill the user goals.

How it works. This is knowledge of the internal structure of the device and the principles of its mechanism.

If this classification of device knowledge is at all correct, it should be possible to classify the descriptions generated by subjects into the three categories of knowledge listed above.

The second question was the correctness of the intuition that since knowledge of the function and operating procedures of the device are the most important and useful in interacting with devices, people's descriptions should emphasize these types of knowledge, while knowledge of how the device works would be very scanty.

The third question was whether people's unconstrained descriptions of devices would show any manifestations of their knowledge being organized in terms of schemas.

Method

Materials and Design. Seven pieces of electronic equipment were selected that varied in familiarity to expert and naive people. These are described briefly in Table 1. Each subject described each device, with the devices being presented in a fixed order, which is the order that they are listed in Table 1.

Devices 1, 2 and 3, a clock, radio, and tape recorder, were chosen to be very familiar to all subjects. Device 4, the volt-ohm-milliameter (VOM) is a standard piece of electronics test equipment. Device 5, the Microvolter, is a very unusual piece of laboratory equipment, but if understood, is actually very simple to an expert. Devices 6 and 7 were chosen to be quite unfamiliar even to the expert. Device 6, the Shock Scrambler, is an extremely simple device used to shock rats in psychology labs, but is unfamiliar to the typical electronic expert. Device 7, the Phi-Phenomenon Demonstrator, was a "home-made" device used to demonstrate apparent motion by flashing two lights alternately at an adjustable rate and phase relationship. The lights were not supplied with the device. Not only was the function of this device unfamiliar to experts, but since it was built by amateurs, it violated certain common conventions in electronic construction. Relevant further details on the devices will be provided below as needed to describe the results.

Subjects. Subjects with varied backgrounds were recruited through campus advertisements and personal contacts. Their characteristics are summarized in Table 2, which classifies them in terms of electronics background as fully naive, naive, partially expert, and fully expert. Notice that there is an association between sex and naivete with electronics. Future experimentation will have to take this into account. Since efforts to locate and recruit female electronics experts were not successful, it is probably preferable to use only male subjects when expertise is manipulated. Subjects were paid $5.00 for participating. The experiment lasted about 1 hour.

Procedure. Subjects were run individually. After writing a brief resume of their electronics experience, subjects were seated at a table. The subject then read a set of written instructions, which were further explained orally. The experimenter then brought the first device and placed it in front of the subject.

The subject would then describe the device, being free to handle it and to manipulate the controls, but not allowed to disassemble it or plug it in. After completing the description, the device was removed, and the next one brought in. The devices were stored out of sight when not being described. The experimenter was present the entire time. The subject was videotaped while describing the device, with care taken to ensure that motions of the hands while indicating or manipulating parts of the device were recorded.

Table 1

Devices Used in the Description Task

1.	Alarm Clock	An ordinary cheap electric alarm clock with snooze alarm and lighted dial. The sweep second hand had fallen off and was barely visible in a corner of the face of the clock.
2.	Radio	A good-quality large AM-FM portable radio, powered either by batteries or AC, with a telescoping rod antenna, bass and treble controls.
3.	Recorder	A somewhat unusual portable cassette tape recorder with "piano-key" controls, but no "eject" button, and with an unusual record button.
4.	Multimeter	A standard volt-ohm-milliameter (VOM) of good make, with a range switch, zero ohms knob, and polarity/AC switch; without probe wires.
5.	Microvolter	A specialized audio-frequency attenuator of excellent make. No power required: Has a large centrally located meter, two large dials, one a multiplier range selector, the other calibrated 0-100, input connector on the left, and output connector on the right.
6.	Scrambler	A shock grid scrambler used to electrify rat cage floors. A small box wth a large "voltage" knob calibrated 0-100, a red pushbutton, a red indicator light labelled "shock", two connectors labelled "remote", and a set of several connectors for the grid. An AC power cord. Cheap-appearing construction.
7.	Demonstrator	A phi-phenomenon demonstrator shop-built by amateurs. A grey box with lid. Front panel has "power" switch, pilot light, two connectors at top left labelled "A" and "B", a large dial calibrated in "CPS" and "MS". Below dial, a toggle switch labelled "RATE" and "PHASE", and a three position toggle labelled "A-B" and "B-A". Heavy power cord and fuse holder on back panel. Opening lid gives view of chassis with transformer, vacuum tubes, potentiometer, and rear of connectors.

Table 2

Subject Characteristics

Subject Number	Classification	Sex	Training	Experience
1	Full naive	F	None	None
4	Full naive	F	None	Some consumer products (e. g. stereo)
5	Full naive	F	None	None
9	Naive	M	1 yr. H.S.	Limited (Sound systems mostly)
2	Part expert	M	None	Much hobbyist experience
7	Part expert	M	2 yr.college Physics Grad student	Fairly wide experience
3	Full expert	M	EE. BS	Extensive professional work
6	Full expert	M	EE,BS, PhD Physics	Extensive professional work
8	Full expert	M	EE undergrad	Some profes-sional work

Instructions. The instructions were intended to produce full and broad descriptions that avoided too much detail. Subjects were asked to "tell us as much about the device as you know, or can figure out by examining it . . . we are not interested so much in the depth of your knowledge as in its breadth. Thus, we do not want you to get bogged down describing intricate details of one aspect or part of the device. Instead, tell us broadly what you can about it." Note that no attempt was made to influence the kind or type of information to be provided. The instructions also warned that the devices ranged from very familiar to quite unfamiliar.

After the first two subjects were run, it seemed to be necessary to supplement the instructions, because the subjects seemed to feel awkward about describing everyday devices. A "cover story" was provided orally after the written instructions in an attempt to alleviate this problem. The third subject was told to imagine that the experimenter (who was always present) was from the Amazon jungle and would need to have each device fully explained. This subject produced frequent references to the problems of obtaining electrical power in the jungle. The next subject was then told a different cover story, that they should pretend that the experimenter was from a high technology culture in another star system, but knew nothing of earth technology. This appeared to work, and was retained for the remaining subjects. These supplemental instructions appeared to be irrelevant for the expert subjects, but apparently did help the naive subjects to be more comfortable and productive.

Results and Discussion

Analysis. The first step in the analysis was to prepare transcriptions of the descriptions for each subject and device. These transcriptions included not only the verbal statements of the subjects, but also which features or controls of the device they were indicating or manipulating. After preliminary examination of the tapes, a set of categories for the various types of statements was defined. These are listed and defined in Table 3. The transcriptions were then summarized in terms of the statement categories, to eliminate redundant words and irrelevant statements. Each summarized statement was then divided into idea units to provide a rough quantification of the amount of information. An idea unit was defined as either a clause, or a phrase introduced by a verb participle. The number of idea units in various categories was counted to provide a measure of the amount of information of various types generated. Another property of the protocols that was quantified is the order of first mention of the categories. This was obtained by finding the first appearance of each category in each protocol, and numbering these items serially. Hence, the very earliest mentioned category had a first mention number of 1; the number of the last mentioned category depended on how many different categories the subject used. The note and comment categories were disregarded in the first mention numbering. It should be noted that only the amount and distribution of statement types was of concern; no attempt

Table 3

Scoring Categories

.ABEL: the name given to the device, for example, subject 02 described device 2 as an "AM/FM radio".

'UNCTION: what the device is used for. For example, subject 03 on device 1 (alarm clock) stated, "it indicates what time it is".

:ONTROL: a part externally located on the device, usually a knob or a switch, that can be controlled by the operator for some desired effect. For example, subject 03 on device 2 (AM/FM radio) refers to (J) as the treble knob.

(a) Identifies (ID): the name good appropriate label given to the device by the subject, e. g.: SUB03, device 2, (J) treble knob.

(b) Purpose: what the subject thinks the control is used for. Subject 03 on device 2 again: (J) treble - "so that more high notes come out".

(c) Effect: what occurs when the control is used. For example, subject 04 on device 3 (tape recorder) said that the "rewind returns the tape to the beginning".

(d) Procedure: steps or a list of directions for control operation. Subject 05 described the procedure for setting the alarm on device 1 (alarm clock): (1) push (g) in.

:ONNECTOR: a hook up for a lead or jack which may indicate either that the device is incomplete or that other auxiliary components can be hooked-up to the device (e. g. earphone jack test lead, etc.). Many examples came from device 4 (VOM) which required alligator clips to use the meter.

(a) ID: the label that the subject refers to.

(b) Purpose: what the connector is used for. For example, subject 08 on device 4 (VOM) described that the connectors I and J were "for probe attachment".

Table 3 (continued)

(5) POWER: the source of power, if any, used to operate the device, for example, a subject 09 said that device 2 (AM/FM radio) "is electricity driven and battery powered".

(6) FEATURE: distinct feature of the device that is not operator controlled. A good example for the FEATURE category came from subject 04 on device 1 (alarm clock): "it has a lighted dial"

(a) ID: identifies the feature

(b) Purpose: what the feature is for. Of course, one would think a dial-lite on an alarm clock would allow the hands of the clock to be seen in the dark.

(7) INTERNAL FEATURE: a distinct feature that is inside the device and not operator controlled. This category is convenient when a door on the device enables the subject to peek inside the device. Device 7 had such a door which revealed internal parts like tubes, fuses and a transformer inside; which would fit into this category.

(8) INDICATOR: a pilot light that monitors some functioning of the device. An indicator would then be an on/off light etc.

(a) ID: identifies the indicator.

(b) Purpose: what the indicator is for.

(9) OUTPUT: a signal transmitted by the device that is not characteristic of an indicator. Severel of the devices had output. The radio and tape recorder for example, transmit sound waves and the phi-phenomenon sends out electrical pulses to two light bulbs.

(a) ID: identifies output

(10) BEHAVIOR: what the device will do under conditions of operation. Usually not operator controlled. For example, subject 07 on device 1 (alarm clock) said, "the hands move round in circles".

(11) HOW IT WORKS; how the device works based on the internal functioning, circuitry and parts. For example, subject 06 said that the alarm clock works by "a synchronous motor inside".

Table 3 (continued)

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(12) PROCEDURE: a list or set of instructions for performing some operation of the device. For example, many of the subjects described the procedure for recording on a cassette tape (device 3).

(a) Goal: stated purpose or reason for performing the procedure.

(b) Steps: Step by step procedure given by the subject to achieve the goal even though the steps may be out of order or incorrect.

eg (subject 03, device 3):

```
PROCEDURE
  GOAL: operate tape recorder
  STEP (1): check (N) for batteries
       (2): open this (B)
       (3): put in tape
       (4): close (B)
```

READS LABEL: when subject reads off any lexical information from the device. This category may be listed by itself or as a sub-category under any category. For example, subject 03 on device 3 read off a label: "label says C cell times 4".

(14) NOTE: A statement concerning device operation, control, or used to express an important piece of information under any category eg (SUB03, Device 04): "batteries are used for resistance measurements".

(15) COMMENTS: any general statement not directly or specifically related to the device. A subject may deviate or digress and explain, as subject 03 did on Device 3 (tape recorder), that head cleaner can be bought in a local store.

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was made to assess the accuracy of the statements. Hence, a naive subject may have been credited with more information about how the clock works than an expert, even though it was wildly inaccurate.

For purposes of comparing expert and novice responses, the three _full experts_ described in Table 2 will be designated as _experts_, and the remaining six subjects as _non-experts_.

Order of First Mention. Table 4 shows the mean order of the first mention for all subjects. Since the differences between expert and naive subjects were very slight, only the overall means are presented. As can be seen, the label of the device was quite consistently produced first, followed later by either the function or the power source of the device. There is considerably less consistency in the order of first mention of the remainder of the categories, as can be seen by their similar and late order of mention numbers. However, there is a tendency for the external features of the device to be mentioned earlier then the abstract features such as the procedures and behavior. This corresponds to the informal observation that after labelling the device, and providing its function and power source, subjects then point out and describe each feature before going on to describe how it works or behaves.

Knowledge Types. To provide a clear picture of the amounts of device knowledge of different types, the categorization shown in Table 3 was simplified into the categories listed in Table 5. The simplification consisted of aggregating all statements of similar content across the features of the device. Thus all labels or identifiers are grouped together, both for the whole device and the individual features. The aggregation was also done for statements of function and purpose, statements of effects and behavior, and procedures. The classification of how-it-works statements was not modified. The "other" category includes all other statement types, but notes and comments were not included. Table 5 shows the mean number of idea units for each device in each category for all subjects, for subjects defined as fully expert, and subjects defined as non-expert. Also included are these means expressed as a percentage of the total for the subject group.

Considered over all subjects, about a quarter of the information appears as function and purpose statements, and another quarter as procedures. Only about 15% of the information consists of how-it-works information. Hence, as expected, most of the information supplied in this task is function and operation knowledge.

Comparing the expert and non-expert groups in Table 5 yields some surprises. First of all, experts produce much more information than non-experts (about 73% more). This difference appears in every category except, surprisingly, how-it-works knowledge. Although experts and non-experts produce very different absolute amounts of information, their distribution of information is very similar. Examining the percentages shows that

Table 4

Mean Order of First Mention
of Major Description Categories

Category	Mean Order
Label	1.3
Function	3.0
Power	3.0
Control	4.2
Feature	4.4
Connector	4.6
Output	4.8
How-it-works	5.2
Internal Feature	5.2
Procedure	5.3
Indicator	5.3
Behavior	5.3

Table 5

Mean Idea Units in Condensed Categories
for Expert, Non-expert, and All Subjects

Category	Expert	Non-expert	All
Labels	6.7 (16%)	4.4 (18%)	5.1 (17%)
Functions purposes	9.9 (24%)	7.0 (29%)	8.0 (26%)
Effects, behavior	4.2 (10%)	2.9 (12%)	3.4 (11%)
Procedures	15.1 (36%)	4.5 (19%)	8.0 (27%)
How-it-works	4.3 (10%)	4.4 (18%)	4.4 (15%)
Other	1.6 (4%)	1.0 (4%)	1.2 (4%)
Totals	41.8 (100%)	24.2 (100%)	30.1 (100%)

the only substantial difference in distribution of information is that the experts emphasized procedural information far more than non-experts. As shown below, this pattern is dependent on, but not contradicted by, which device is involved.

Individual Devices. Tables 6a and 6b correspond to Table 5, with the additional dimension of device. There are substantial differences in how much information was said about each device, and a clear interaction of expertise with device. Notice that despite their expertise, under the scoring system used, the experts did not say more about the unfamiliar devices 6 and 7 then non-experts did, and the same was true for the familiar and simple device 1, the alarm clock. (Recall that the accuracy of the statements was not a factor in the scoring.) However, for all other devices, the experts produced more information than the non-experts.

The key result is that experts made more procedure statements than non-experts for devices 1 through 5 but not for devices 6 and 7. The differences between experts and non-experts in all other categories are either slight or nonsystematic for all devices. Surprisingly, non-experts show a clear tendency to say more about how-it-works than experts on everyday devices. The VOM stands out because it is a multipurpose testing instrument known only to experts, who thus had a wealth of procedural information about it. Furthermore, experts stated more how-it-works information for this device than the familiar ones, perhaps because this information is sometimes needed for correct use of the instrument. Thus the result noted above, that experts produce and emphasize procedures more than non-experts, holds even for everyday devices.

Description Content. In order to characterize the common or core features of each device, the response contents were condensed and classified by the above-described categorization, and then the responses in each category were sorted into distinct content groups, and the frequency of each distinct content form counted. Only responses judged to be produced by at least two subjects are included. Due to the small sample, and great variation in subject's statements in this task, these data are of limited quality. Tables 7 through 13 summarize the content of the device descriptions. The greater the number of subjects describing a particular feature in the same way, the more that feature description can be considered as a schema property. This may not always be true, since subjects do not state many features that are certainly strongly characteristic of the device, such as that a clock has hands. Experiment 2 addresses some of these concerns.

Table 7 shows these results for the alarm clock. There is strong agreement on the controls and the behavior of the clock. Note the high total frequency of statements about the power source. In contrast, the label and function statements are somewhat inconsistent. A similiar pattern appears for the radio, shown in 8. Notice the impoverished how-it-works category; very little detail was provided. In contrast, all of the controls were described fairly consistently, as were items related to the power

Table 6a

Mean Number of Idea Units for Each Device, for Experts (E) and Non-Experts (N)

Devices

		Clock 1		Radio 2		Recorder 3		VOM 4	
Label, Identifiers									
	(E)	3.3	(9%)	11.33	(20%)	12.33	(18%)	5.33	(7%)
	(N)	3.0	(10%)	8.00	(27%)	8.33	(19%)	1.67	(7%)
Function, Purpose									
	(E)	5.67	(16%)	14.67	(26%)	14.33	(28%)	11.00	(14%)
	(N)	6.33	(20%)	9.00	(30%)	11.67	(26%)	5.50	(23%)
Effects, Behavior									
	(E)	12.00	(34%)	6.67	(12%)	5.33	(8%)	3.33	(4%)
	(N)	5.67	(18%)	3.83	(13%)	3.67	(8%)	3.17	(13%)
Procedures									
	(E)	8.33	(23%)	19.33	(34%)	18.00	(26%)	50.67	(63%)
	(N)	4.50	(14%)	1.00	(3%)	8.00	(18%)	11.17	(47%)
How-it-works									
	(E)	4.00	(11%)	2.33	(4%)	10.33	(15%)	10.33	(13%)
	(N)	10.50	(39%)	6.50	(22%)	10.50	(24%)	1.00	(4%)
Power, Other									
	(E)	2.33	(6%)	2.00	(4%)	2.67	(4%)	.33	(0%)
	(N)	1.17	(4%)	1.33	(4%)	2.17	(5%)	1.17	(5%)
Total	(E)	35.63	(100%)	56.33	(100%)	67.99	(100%)	80.99	(100%)
	(N)	31.17	(100%)	29.66	(100%)	44.34	(100%)	23.68	(100%)

Table 6b

Mean Number of Idea Units for each device, for Experts (E) and Non-Experts (N)

Devices

	MVolter 5	Scrambler 6	Demonstrator 7
Label Identifiers			
(E)	3.66 (23%)	4.00 (25%)	6.67 (34%)
(N)	1.17 (16%)	3.50 (21%)	4.83 (29%)
Function, Purposes			
(E)	4.00 (26%)	7.00 (44%)	7.33 (37%)
(N)	3.66 (50%)	7.00 (42%)	6.00 (36%)
Effects, Behavior			
(E)	.67 (4%)	.67 (4%)	1.00 (5%)
(N)	.83 (11%)	.83 (5%)	2.50 (15%)
Procedures (all)			
(E)	5.00 (32%)	2.00 (12%)	2.33 (12%)
(N)	1.50 (20%)	3.17 (19%)	2.00 (12%)
How-it-works			
(E)	1.00 (6%)	.67 (4%)	1.33 (7%)
(N)	.00 (0%)	1.50 (9%)	1.00 (6%)
Power, Other			
(E)	1.33 (8%)	1.67 (10%)	1.00 (5%)
(N)	.17 (2%)	.67 (9%)	.33 (2%)
(E)	15.66 (100%)	16.01 (100%)	19.66 (100%)
(N)	7.33 (100%)	16.67 (100%)	16.66 (100%)

Table 7
Description Content Summary for
Clock, Device 1

Label	Alarm clock (3) Electric alarm clock (2) Simple/cheap clock (2)
Function	Tell time (4)
Controls	"snooze" alarm button (7) Alarm control (9) Set alarm and time (7)
Power	AC (4) Plug into a wall outlet (3)
Feature	Dial light (6) second hand (2) hour hand (2) Has alarm (2)
Behavior	Hands rotate (6) When time = alarm hand, alarm sounds (2)
Procedure	One for setting alarm (most information with controls)
How-it-works	Motor runs at fixed speed (3) Synchronous motor (2) Gears inside (3) About alarm (3)

Table 8
Description Content Summary for
Radio, Device 2

Label	Radio (3)
	AM-FM radio (2)
	Portable radio (2)
Function	Listen to music, radio stations (2)
Controls	Tuning (4)
	Power switch (8)
	Band selector (7)
	Volume (8)
	Treble and bass (4)
	Treble (3)
	Bass (3)
	AC/DC selector (4)
	FM antenna (4)
Connectors	Earphones (2)
Power	AC or battery (6)
Features	Battery compartment (5)
	AM/FM radio (4)
	A handle (2)
	Dial scales (2)
Indicators	Tuning indicators (2)
Output	Speaker (2)
Procedure	Listen to AM (2)
	To tune to station/listen, etc. (5)
How-it-works	Catch electromagnetic radiation (3)
	Radio waves - sound waves (3)
	Picks up radio waves (2)

source. The basic procedure described is that of tuning in a station. The cassette recorder, shown in 9, produced very consistent responses. The label and function are fairly clear, with some consistency showing in the impoverished how-it-works category. Again, the power was often mentioned. All of the controls, inputs and outputs were described. Although not many subjects described the procedures in terms of the individual controls, they did emerge as having two basic types. Apparently, despite its relative complexity, the cassette recorder is a fairly "standard" device to the subjects.

The VOM, Table 10, was labelled correctly by three of the more expert subjects. Its basic classification and function was recognized by several more subjects. However, only one of the controls was consistently described, and only the more knowledgeable subjects described other controls or procedures. Interestingly, the only how-it-works statement produced with any consistency is largely an operational detail; occasionally the batteries must be replaced.

The MicroVolter, Table 11, produced no clear label or function responses and basically only the expert subjects described any of the other features. It did not show in the content classification used here, but the experts eventually understood that the device was an attenuator of some sort.

The Shock Scrambler, shown in Table 12, resembled some of the more familiar devices in that the controls, connectors, and power were consistently described. However, the label, function, and procedures were not consistent. This pattern would be expected from the combination of simplicity and unfamiliarity of the device. Finally, the Demonstrator, shown in Table 13, produced descriptions of many of its features that were recognizable standard features of electronic devices, such as the power switch, and the large dial. Since there were a large number of hypothesized statements, these are also included. Again, the power-related items are well described, especially the fuse holder, on-off switch, and pilot light.

Conclusions

Categories of Device Knowledge. As proposed, device knowledge does seem to classify naturally into the categories of the device function, the procedures for operating the device, and how the device works. However, a couple of additional general categories appeared in the protocols. The first is how the device behaves. This is knowledge about what the device would do under various conditions of control settings. For example, some subjects described the behavior of the alarm clock without reference to either the user's goals, or an operating procedure, or to how the clock works inside. Rather, they stated basic facts about the behavior of the clock such as, that when the hour hand

Table 9
Description Content Summary For
Recorder, Device 3

Labels	Cassette tape recorder (3) Tape recorder (4)
Function	Play of recorded signal, sound, or/information on tape (6)
Controls	Cassette door (6) Record button (4) Tape movement controls (3) Rewind (5) Play (5) Fast forward (6) Stop (5) Volume (6)
Connectors	Microphone jack (4) Remote (connector only) (2) Auxiliary speaker (3) Earphone (6) AC powered (5)
Power	Battery or AC (6)
Features	Handle to carry (2)
Intern. Features	Heads (2)
Output	Speaker (5)
Procedure	To record (3) To listen - playback (2) To operate/use (2)
How-it-works	Signals put on/off the tape (5)

Table 10
Description Content Summary For
VOM, Device 4

Label	Volt-Ohm Meter (3) Meter (of some sort) (2)
Function	Measures electrical values (4) Measures volts and ohms (2)
Controls	Selector (6) Ohms adjustor (2) Select AC, DC+, DC- (2) Reverse polarity (3)
Procedures	Measure current (2) Reading scales (5) Measure resistance (3) Measure AC (2) Measure DC (3) Zero meter (4)
How-it-works	Measurements (3) Batteries power resistance

Table 11
Description Content Summary For
Microvolter, Device 5

Label	None (9)
Function	no consistent responses
Controls	Controls output (4) Multiplies (3)
Connectors	Input (3) Output (3)
Power	Neither AC nor batteries (2)

Table 12
Description Content Summary For
Scrambler, Device 6

Label	None (3)
Function	Used for shock in experiments (3) Outputs voltage (2) Scrambles shock (2)
Controls	Voltage knob (6) Shock button (4)
Connectors	For grids (4) For remote control (5)
Indicators	Power/shock (4)
Power	Plug in (6)
Procedures	None mentioned by more than one subject

Table 13
Description Content Summary For
Phi-phenomenon Demonstrator, Device 7

Label	Signal generator (2)
Function	Generate signals (2)
Controls	On/off switch (6) Mode/difference (2)
Indicator	Pilot light (7)
Output	Two Signals (2)
Connectors	Outputs (3) Inputs (2) Unusual (2)
Power	AC/wall (4)
Feature	3 pronged plug (4) Fuse (6)
Internal feature	Tubes (2)
Hypothesized funct.	Sound related (4) Putting out something (2)
Hypothesized contr.	Rate or frequency or tune (5) Rate or phase (4)

l the position of the alarm hand, the clock would make a
g noise if the alarm lever was pulled out.

second new type of knowledge is where the device gets its
This type stood out very strongly in the protocols, and
ither expected nor predicted. An important question is
r the early mention of the device power source, and its very
nt mention, stems from the strong perceptual salience of
related features, or whether it reflects a basic high
ty given to power sources in the knowledge representation.

ierarchial Device Knowledge. Another important aspect of
knowledge that was revealed by this experiment was that the
ries of label, function and operation appeared not just at
vel of the whole device, but also at the level of individual
ls, connectors, and other features of the device. This is
from the very common pattern of descriptions in which
ts pointed out each control, stated its function or purpose,
hen provided a procedure for using it. Thus the categories
ice knowledge appear to apply hierarchially, both to whole
s, and to their parts.

rocedural Emphasis. Despite the extremely undirected
ctions, subjects appeared to talk mostly about how to
e the device and what the device is for, and very little
how it works. Apparently, how the device works is not
ered very important under the very unconstrained description
ctions. It is surprising that even the experts did not
e much of this information. However, some experts indicated
they could provide considerable detail on how the devices
, but did not want to. This suggests that this feature of
pert descriptions is a result of the demands involved in the
sional practice of electronics expertise. Normally, when an
onics expert is asked to describe a device to another
, it would be under conditions in which the other person is
n electronics expert, but rather only a user of the device.
s case, a detailed explanation of how the device works would
rgely irrelevant, whereas what the device is for, and how to
e it, would be the most important information to provide.
under the general instructions used here, experts may have
carried out their customary explaining function, and as a
, said very little about how the device works.

trong Evidence for Schema Use. The hypothesis offered above
at people have schemas for familiar classes of devices such
rm clocks or tape recorders. These results show that
ts clearly recognize familiar devices, and can generate
tent statements about them. But this does not strongly
that their knowledge is organized in terms of schemas. Some
ersuasive evidence that schema knowledge is present appears
e infrequent, but striking, cases where subjects clearly
as if they have expectations of default schema slot values
e features of everyday devices. Since these events were not
, and were very idiosyncratic, the only presentation of them
will be attempted here is based on informal observation of

the taped protocols. Such events could be systematically studied using experimental procedures expressly designed for the purpose.

The manifestations of apparent schema use can be classified in terms of whether the subject is using *conventions*, *general properties*, *expectations of features*, or *patterns of features*.

Examples of conventions that appeared are that the standard position for an on-off switch is *down* for *off*, and that the clockwise rotation of an knob gives more of whatever quality that the knob controls. Color coding conventions were in evidence; for example, a few subjects mentioned the color coding convention in which red represents positive, and black represents negative. Several subjects mentioned the use of color coding on meter dials, or the use of corresponding colors of calibrated scales with legends on selector switches.

Some other manifestations of schema use fell into the category of general properties of devices. For example, the Demonstrator was quickly recognized as being an old piece of equipment by several subjects largely on the basis of the use of vacuum tubes, and the part- and full-experts readily recognized that it was constructed by an amateur in a shop, rather than being factory-built.

The strongest manifestations of the use of schemas were expectation events, in which the subjects attempted to find certain features of the device that they expected to be present, but were in fact missing. For example, on the alarm clock, the second-hand had come off of its shaft and was resting barely visible in a corner of the dial. Two subjects attempted to locate the second-hand, and after spending some time searching for it, appeared to be gratified when they found it. In describing the portable radio and portable tape recorder, four subjects appeared to expect there to be a power cord accompanying the device. On the VOM, two subjects indicated that they expected to see test leads in conjunction with the device. Two persons attempted to find the eject button that most cassette tape recorders have; in one case this search was very dramatic; the subject tried every button, while commenting that she was trying to find the eject button.

Some of the more expert subjects demonstrated a knowledge of overall patterns of features on a device that could be used to infer some of the characteristics of the device. This suggests that they have some very general device schemas. For example, three subjects decided that the Microvolter was an attenuator, or a modifier of some sort, because there were calibrated dials, and both input connections and output connections, but no visible source or controls for power. The only logical analysis of the device consistent with these features is that it must do something with a signal that comes in and goes out, and the only such modification that would not require a power source would be simply to weaken, or attenuate, the signal. Another case appeared with the Demonstrator. One subject commented that the presence of the

output connectors on the device, together with the large calibrated dial, indicated that it was a signal generator, but he was surprised to see that there was no amplitude control, which usually appears on a signal generator.

In some cases this expert knowledge of overall patterns and specific schemas was misleading. For example, one of the full-expert subjects, whose descriptions otherwise were extremely competent, misconstrued the Demonstrator almost completely. This was a result of being misled by the two connectors in the upper left-hand corner of the front panel. These connectors in fact were output connectors for two neon bulbs that would flash alternately to demonstrate the Phi-phenomenon. But, since the left-hand front position is normally reserved for input connectors, the subject initially classified them as input connectors, and then arrived at a very exotic analysis of the device. He was also greatly puzzled by the fact that the cycles per second calibration on the scale did not agree in the usual way with the millisecond calibrations. He was the only subject who noticed this, and he spent considerable time trying to understand it. The subject eventually conceded defeat and gave up attempting to understand the device, apparently because he knew that his analysis of the device was very implausible. Similar phenomena happened with some of the other expert subjects on one or more of the devices.

This is a rather limited sample of how experts can be mislead. But the general conclusion that can be drawn is that having expert knowledge of schemas for devices can be a disadvantage if the wrong schemas become instantiated too early in the process, or without taking into full account all of the specific details. So, the subject who initially misconstrued the front panel connectors of the demonstrator was led down the garden path for a very long period of time, while some less expert subjects classified the Demonstrator as a type of signal generator on the basis of other features, such as the large calibrated dial, and then immediately considered the two connectors to be output connectors. Thus schemas can be mistriggered and when they are, the results can be seriously wrong. Overall, this conclusion is additional support for the hypothesis that device knowledge is organized in terms of schemas.

EXPERIMENT 2

The purpose of Experiment 2 was to obtain a characterization of the schemas for everyday devices based on retrieval from memory, rather than on description of a presented device. The approach was based on Graesser's (1981) method. If a large number of subjects are asked to generate descriptions of some object, and the components of these descriptions are then classified, then the components that are produced by many subjects make up the population's schema for the object. This study was designed to answer some questions resulting from Experiment 1, which concern the extent to which the task demands of the description procedure would limit the content of the descriptions.

The first question concerned getting a more believable description of the schematic features of a device. For example, the clock hands were rarely described by subjects in Experiment 1, even though they must be a central feature of clocks. In this study, subjects were asked to produce lists of features that could be used to recognize the device, and also features that would be expected to be present on the device.

A second question concerned the very limited amount of how-it-works knowledge appearing in Experiment 1. As mentioned above, subjects, especially experts, may be following a social convention in which procedures are emphasized in describing devices to another person. In this study, subjects were directly asked to produce how-it-works knowledge, thereby perhaps giving a more realistic assessment.

The third question concerned the surprising prominence of power source information in the description task. As mentioned above, one explanation could be the perceptual salience of power-related features. The power cord, or battery compartment door, are large and prominent visual and tactile features. Another explanation would be that power sources are a central aspect of electronic devices for most people, and are thus a mandatory part of their descriptions. This issue could be addressed by examining how often power source features were listed from memory, as opposed to included in the description of a present device.

For this study, ordinary college student subjects and everyday devices were used. This was necessary and convenient, because clearly a person can not provide a description of an unfamiliar object, and non-experts are readily available. However, the four devices were chosen so that three of them were the same as the everyday devices studied in Experiment 1. The devices used were an electric alarm clock, a portable cassette tape recorder, a portable AM/FM radio, and a black and white television set.

Method

Subjects. The subjects were students of both sexes at the University of Arizona, recruited through campus advertisements. A total of 21 subjects participated in the experiment.

Materials and Design. Each subject was asked to describe four everyday devices. These were labelled for the subjects as: (1) *ordinary electric alarm clock*, (2) *AM/FM portable radio*, (3) *portable cassette tape recorder*, and (4) *black and white television set*. For each device, five aspects of the device were to be described, and were carefully explained to the subjects as follows: (1) *Functions*: "What is the device for? What is its function?" (2) *Recognition Features*: "How would you recognize one? That is, if one had never seen one before, how would one recognize it?" (3) *Expected Features*: "What features would you expect to see on it? By "features", we mean things like:

controls, knobs, buttons, displays, indicators, screens, doors, lids, connectors, plugs, and so forth". (4) Operating Procedures: "How do you use, or operate the device? Again, if one had never seen one before, how would one go about using it?" (5) How-it-works: "How does the device work? We are interested in your description of this aspect of the device even if you feel that you don't really know. You probably have at least some rough or intuitive idea about how these devices work. This kind of understanding is what we would like to know about. Technical jargon is not at all necessary".

Each subject was given a response booklet consisting of five pages for each of the four devices. At the top of each page was the label of the device, followed by the description of the specific aspect being inquired about. The rest of the page was left blank for the subject to write his or her response for that aspect. The devices and aspects appeared in a fixed order of apparent increasing complexity, the orders in which the devices and aspects are listed above. After reading a set of written instructions, each subject simply began writing their responses to each page in order. All subjects finished the experiment within an hour. Each subject was paid $5 for participating.

Results

Scoring procedure. The goal of the scoring was simply to obtain the frequency with which each distinct item of the aspects was produced. Each aspect for each device was scored separately. The scoring was done in two passes, the first pass consisting of noting and tabulating all of the different item mentioned by the subjects, and the second pass consisting of rescoring the protocols using the final set of item categories to obtain a final scoring for all subjects. In the case of the recognition features, the expected features, and the function of the device, this scoring scheme was very straightforward. The only possible problem is that subjects often did not clearly distinguish the recognition and expected features in their protocols. However, as will be shown below, the distribution of features mentioned under these two aspects was indeed different.

The scoring of the operating procedures aspect was slightly more complicated in that operating procedures consist of a series of steps whose order should be preserved, and the procedures were often, but not always, described in terms of a method for fulfilling a goal. In this case, the scoring was done in terms of a specific step, such as pressing the record button on the cassette recorder, in order to fulfill a possibly stated goal, such as recording a lecture. The scoring consisted not only of noting which steps an individual subject mentioned, but also of recording the order in which that step appeared in a procedure for the designated goal. However, no analysis of the order information is presented in this report.

Finally, the scoring for the aspect of how the device works essentially consisted of scoring for the presence of "ideas". The scoring categories in this case were not as well-defined as the feature or procedural aspects. The variation in the scoring results for how-it-works statements is thus much greater than for the other aspects. For example, some subjects referred to the black and white television set as a device that _converts waves in the air into a picture_ while others said it _converts waves from a broadcasting station into a picture_. These two statements were similar but were scored as separate categories, because of the difference in the idea that the _waves are transmitted from a broadcasting station_.

The results are shown in Tables 14, 15, 16, and 17, which show the frequency with with each feature was described under each aspect of each device, for the 21 subjects. In order to produce shorter and more concise tables that do not include the distraction of individual subject idiosyncrasies, each table shows only those features which were produced by at least five different subjects, or at least two subjects for the less consistent how-it-works information.

It is clear from the Tables that for these everyday devices, there is a high degree of agreement between subjects concerning the function, features (both recognized and expected), and procedures. The how-it-works knowledge provided by subjects was less consistent than the other aspects of the devices, which could be at least partly due to scoring artifacts. But there is another explanation for the low consistency. The expected features of a device can be listed on the basis of the concrete observable features of the device itself, whereas the how-it-works knowledge is based on knowledge of the internal and invisible operations going on inside of the device. Consequently, a lack of consistency in the how-it-works knowledge may simply reflect that people do not have as clear an idea of how a device works as they do of how it looks and how to operate it. This tendency is apparently more pronounced with more complex devices. That is, the how-it-works information for the television (Table 17) is extremely inconsistent, as well as limited in quantity.

There is some overlap between the recognition features and the expected features, but there is a clear difference in distribution of these features, and the overlap is not complete. For example, a high-frequency recognition feature for the clock is _face with numbers 1-12_. This is also a high-frequency expected feature as well. Similarly, the _cord with plug_ is both an important recognition feature and an important expected feature. However, the information about the clock size and shape that appears in the recognition features does not appear in the expected frequencies. Similar differences and similarities in recognition and expected features appear for the other devices. For example, a _carrying handle_ is a recognition feature of the recorder, but does not show up in the expected features. Thus, the distinction between recognition and expected features is one valid to subjects, even though there is considerable overlap

Table 14

Frequency of appearance of each item
for each aspect of ordinary electric alarm clock

Aspect: Purpose/Function

Freq	Item
14	shows present time
12	indicate present time
11	awaken from sleep
5	reminder: to coordinate activities

Aspect: Recognition Features

Freq	Item
10	has a face with numbers 1-12
10	clock size various & is rectangular or box shaped
9	has 2-3 hands that revolve on central pivot to numbers
8	cord with plug (AC)
7	the longer minute hand revolves once every hour. It measures minutes.
5	the small hour hand rotates once every 12 hours. It measures hours.
5	the second hand rotates once every min. It moves fastest. It measures seconds.
5	Behavior: hands rotate on pivot at different speeds

Aspect: Features

Freq	Item
19	cord with plug (AC)
18	face with incremental numbers
10	time setting knob
10	alarm set knob
10	hands
8	control knobs
7	alarm deactivation button
6	snooze control
5	alarm hand

Table 14 (continued)

Frequency of appearance of each item
for each aspect of ordinary electric alarm clock

Aspect: Procedures for using

Freq	Item
13	Step for Goal c: set current time w/ time set knob.
12	Step for Goal c: plug into AC outlet
11	Step for Goal c: set desired alarm time with alarm set knob
9	Step for Goal c: turn on (pull out) alarm knob to enable alarm
7	Goal c Behavior: alarm rings
6	Step for Goal b: set alarm time as desired with alarm set knob
6	Goal c Behavior: hands move
5	Goal b: set alarm
5	Goal c: to operate
5	Step for Goal c: get current time

Aspect: How-it-works

Freq	Item
11	power source fixed AC ratio to drive motor for clock to work
10	gears are calibrated to move hands at a fixed rate
6	motor regulates gears and is regulated by power
6	plug in clock for power
4	motion of hands indicates the time unit
3	electricity drives moving display mechanically
3	motor drives hand at certain rate
2	when alarm time & current time are the same and if button pulled, noise is produced

Table 15

Frequency of appearance of each item for each aspect of the AM/FM portable radio

Aspect: Purpose/Function

Freq	Statement
11	listen to musical entertainment
7	provides information
6	communication receiver
6	(portable) enables listener to take radio anywhere
5	entertainment or listening pleasure
5	listen to news

Aspect: Recognition Features

Freq	Item
16	AM/FM display tuning of numbers
14	rectangular shaped box
8	tuning pointer
7	tuning dial
6	ranges in size adult hand to suitcase
6	antenna
6	speaker(s)
5	has carry handle

Aspect: Features

Freq	Item
17	AM/FM tuning display of frequencies
17	tuning dial
11	tuning pointer
11	volume control
10	on/off button or knob
10	AM/FM band selector
10	antenna
8	speaker(s)
8	battery compartment
7	handle
6	cord with plug
6	control knobs
5	perforated speaker grille

Table 15 (continued)

Frequency of appearance of each item
for each aspect of the AM/FM portable radio

Aspect: Procedures for using

Freq	Item
20	select desired station with tuner
14	turn on on/off switch
14	adjust volume knob to desired level
8	switch AM/FM selector for other stations
5	plug in AC outlet

Aspect: How-it-works

Freq	Item
12	picks up waves from air with the antenna and converts them to audible sound
8	broadcasting station sends out waves, signals
6	runs on batteries
3	tuning knob controls station selection
2	AM mode, carrier signal is amplitude modulated
2	in FM, carrier frequency is to frequency modulation.

Table 16

Frequency of appearance of each item for each aspect of the portable cassette recorder

Aspect: Purpose/Function

Freq	Item
12	to record sound
10	for playback of sounds
7	to play pre-recorded music
6	play back any number of times (preserved sound)

Aspect: Recognition Features

Freq	Item
11	function buttons (on side)
10	(box) rectangular shape
9	cassette tape housing
7	cassette door (window)
5	speaker(s)
5	carry handle
5	cassette tape (rectangle)
5	speaker grille(s)

Aspect: Features

Freq	Item
14	cassette tape door (clear)
11	cassette tape compartment
9	tape play button
9	control buttons
9	tape rewind button
9	cassette tape
8	volume control
8	tape fast-forward button
7	cord with plug
7	tape record button
6	battery compartment
6	speaker(s)
6	microphone jack
6	microphone
5	tape stop button

Table 16 (continued)

Frequency of appearance of each item
for each aspect of the portable cassette recorder

Aspect: Procedures for using

Freq	Item
13	Step for Goal a: put cassette in compartment
11	Step for Goal a: press play button for sounds
10	Goal b: to record
7	Goal c: playback
7	Step for Goal c: depress play
6	Step for Goal a: turn on "on/off" switch
5	Step for Goal a: push eject button, open compartment

Aspect: How-it-works

Freq	Item
9	electrical impulses magnetize iron particles in tape...
9	sound occurs from speaker when impulses are pick up by heads
7	playback, magnetic tape reinduces impulses on tape head
4	runs on batteries since portable
4	imprints on tape are converted to sound waves
3	sound picked up by microphone. converted to electrical impulses
3	spools run tape through device
2	records, playsback, prerecorded material
2	tape moves at constant speed past heads
2	works like the radio

Table 17

Frequency of appearance of each item for each aspect of the black and white television

Aspect: Purpose/Function

Freq	Item
11	provides entertainment
7	picks up & converts electromagnetic waves into picture & sound
5	provide public information

Aspect: Recognition Features

Freq	Item
11	box or rectangle shaped
11	glass screen in front rectangular or square
9	Antenna(e) on top - usually two
9	various knobs or controls (side of screen)
6	vary in size from hand to room
6	cord and plug
5	channel selector
5	speaker
5	volume control

Aspect: Features

Freq	Item
19	glass screen
14	cord with plug
13	channel selector
13	antenna(e)
10	control knobs
8	volume + on/off knob
7	volume knob
6	speaker(s)

Table 17 (continued)

Frequency of appearance of each item
for each aspect of the black and white television

Aspect: Procedures for using

Freq	Item
14	plug into AC outlet
14	turn on ON/OFF
12	adjust volume level
11	turn channel selector to desired channel
7	adjust or extend antenna for better reception
5	adjust picture with controls

Aspect: How-it-works

Freq	Item
5	works like a radio
5	TV waves are received by antenna
4	picture tube converts wave into picture
4	uses waves that are in air
3	images projected from TV station
3	TV receives images & projects them on screen
3	run by electricity
3	images consist of many tiny dots
3	device to get visual & audio waves transmits them to audible sound and visual images
2	TV receives waves. It converts them to sound & picture by transistors, tubes and picture tube
2	picture goes through vacuum tubes to picture tubes
2	TV station converts sound & visual image to electrical signals and sends them

n the specific features involved. Furthermore, there is a tion that some superficial or obvious physical properties of evice, such as its shape, are important in recognition, but cessarily elsewhere.

he main thrust of the results lies in comparing the ptions produced in the two experiments. The general result t the descriptions are different, but compatible. The first sion is that the descriptions from memory are more complete ne descriptions of a presented device. This suggests that description task used in Experiment 1 produces some tions in what people describe about familiar devices; these tions mainly involve leaving out some of the obvious or ed features. This can be seen by comparing which items ed as either expected or recognition features in Experiment the features mentioned in Experiment 1. For example, in ment 1 some of the obviously distinctive features of the clock, such as the numbered dial and the hands, were ned only by a few of the subjects. In contrast, in the ption from memory these properties of a clock are extremely t.

he how-it-works information in this experiment was also more ive and detailed than appeared in the Experiment 1 results. xample, the improvished how-it-works information from ment 1 is clearly not typical of what subjects actually know alarm clocks and cassette recorders. The how-it-works ation shown in Tables 14 and 16, while not very consistent, y shows that a large number of people have some fairly te ideas about how the clock and recorder work. Thus, the n of incomplete feature descriptions and limited -works knowledge observed in Experiment 1 must be a result task demands, rather than a feature of the amount or the zation of knowledge of devices.

he third question motivating this experiment concerned the nt appearance of information related to the power source in ment 1. This is best examined with the set of expected es that all of the devices have in common. Table 18 shows nformation. The Table was generated by choosing all those ed features which appeared for at least two devices out of ır, and showing the frequencies with which they appeared for ther devices. Notice that these other frequencies are ed even if they are below the cutoff value of 5. In y, a total of 46% of these common features had to do with sources, 29% were related to controls, 16% to loudspeakers, fell into other categories.

his distribution of common features is hardly surprising the devices studied. All of the devices used power sources, ny of the devices involved audio output and so had volume ls and loudspeakers. Given that our subjects were ordinary s, and that most everyday electronic devices are inment products, this set of common features includes the nt and standard features of this type of electronic device.

Table 18

Frequencies of Expected Features Shared by Two or More Devices

Feature	Clock	Radio	Recorder	TV	Total proportion
	Device				
Cord w. plug	19	6	7	14	.23
On/off switch	1	10	4	3	.15
Battery compart.	1	8	6	0	.07
Volume control	0	11	8	7	.13
Loudspeaker	0	8	6	6	.10
Speaker grille	0	5	4	3	.06
Control knobs, buttons	8	6	9	10	.16
Handle	0	7	3	0	.05
Vol + on/off control	0	1	0	8	.04

Note. Total proportion column shows the proportion for each feature of the total 201 feature occurrences listed in the table.

The high frequency of features related to power sources was very striking in these results. This suggests that the frequency of their mention in the Experiment 1 description task was not due to simple perceptual triggering produced by the very obvious features of the device such as the cord dangling out the back. Rather, for many people, and many different electronic devices, information about the power source is a frequently-appearing standard property of the device. This means that if there are schemas for devices, and a schema for electronic devices in general, then information about the power source will make up an important section of this schema.

This is an interesting contrast with the point of view of electronic devices that is reflected in engineering text books and other sources on electronics. Often the power source is assumed to be present and need not be further described. For example, a schematic diagram of a complex circuit will simply show where the power source is applied and what the required voltage is. It is not considered necessary to go into any specifics about where this particular voltage ultimately comes from. The technical details of power supplies are generally relatively simple, and if taken up at all, are relegated to a separate section of a text or reference book.

Another consideration is that connecting an electronic device to its power source and turning it on are important in operating the device, meaning that not only are power source features common to many different electronic devices, but are also used in the operating procedures for many different devices. A small result consistent with this is that in Table 16, some subjects included operating the on/off switch in their procedure for the recorder, even though portable cassette recorders normally do not have separate power switches.

A PROPOSED ORGANIZATION FOR DEVICE SCHEMAS

The results from these two experiments strongly suggest that people have their knowledge of electronic devices organized in terms of schemas, which represent the properties of general categories of devices. People have strong expectations that are based on prior knowledge of similar devices; people show fairly high consistency in their descriptions of devices from memory, at least for the concrete features; for many devices within a broad class of devices, such as home entertainment devices, there are recurring groups of features which concern standard sub-parts of devices, such as the power source and the audio output. However, it must be recognized that such evidence of expectations and consistency in prior knowledge does not strongly specify the actual organization of the knowledge. That is, all of these results are consistent with both the idea that device knowledge is highly organized in terms of schemas, and also that device knowledge is organized in terms of an unstructured set of facts, some of which are more salient than others.

Table 19

Schema for a Radio

```
STRUCTURE
  power-device
  tuner-device
  audio-device

LAYOUT
  box shape
  medium size
  tuner-device on front
  audio-device on front
  tuner-device right of audio-device

OPERATION
  IF (Goal is to listen to station X)
  THEN (Do power-device operation
        Do tuner-device operation
        Do audio-device operation)

HOW-IT-WORKS
  station sends signal to tuner-device
  tuner-device sends signal to audio-device
  audio-device sends sound to user
  power-device supplies power to tuner-device, audio-device

BEHAVIOR
...
```

However, the results strongly suggest a hierarchial organization of device knowledge, which is consistent with the schema concept as it is usually advanced, but is not a clear consequence of an unstructured representation. Similar schema knowledge appears not only at the level of the whole device, but also at the level of its parts, or _subdevices_. For example, not only do people show evidence of having schemas for a radio, but they also appear to have schemas for power sources, and so expect to find batteries, power cords, pilot lights, and on/off switches. Furthermore, as in the case of the Phi Phenomenon Demonstrator, they can recognize collections of subdevice features even if the whole device is unfamiliar. Thus, it appears that device knowledge is hierarchial; a given device is viewed as consisting of a collection of subdevices.

In terms of this framework, the schema for a whole device should consist of a collection of subschemas for the individual subdevices. The only features of the device that would appear in the top-level schema would be those that belong to the whole device, while properties of the subdevices would be represented in the subschemas. These subschemas are schemas in their own right, and will be referred to by the schemas for any other device that contains the corresponding class of subdevices.

Such a structure implies that people would operate a new, or poorly learned, device by summoning up the appropriate subschemas for the device, and using the procedure information contained in the subschemas, as opposed to operating the device as a whole. For example, for many electronic devices, and many user goals, the first step in the operating procedure is to get the device "powered up". Almost all devices have fairly standard powering-up procedures, consisting of steps such as plugging in the power cord and then turning on a power switch. Consequently, this procedure can be regarded as being a procedural subschema referred to by procedures represented at a higher level of the device. Another example of schematic procedures would be those for controlling the volume on a device that has an audio output subdevice. However, based on current thinking on cognitive skills (Anderson, 1982), it could be speculated that once procedures for operating the device had been well learned, or automated, they might not be executed or represented as a hierarchial set of schematic procedures, but rather a single automated procedure for the whole device.

The different kinds of information that would appear in a device schema would appear in all of the subschemas. Each schema consists of components for the _structure_ of the device, the _layout_ of the device, the _operation_ of the device, the _how-it-works_ information, and the _behavior_ of the device. Each of the components in a schema is specified only at that level of the device description; thus, all information is represented at as low a level in the schema hierarchy as possible. A rough example appears in Tables 19, 20, 21, and 22 which shows a possible schema hierarchy for a _radio_.

Table 20

Subschema for Power-Device

```
STRUCTURE
  power-cord
  power-switch
  pilot-light

LAYOUT
  power-cord on back of device
  power-switch on lower front of device
  pilot-light on front of device

OPERATION
  IF (goal is to power-up)
  THEN (plug in power-cord
        turn-on power-switch
        check pilot-light)

  IF (goal is to power-down)
  THEN (turn-off power-switch)

HOW-IT-WORKS
  electricity from plug goes through cord to the
  power-switch which controls whether electricity
  goes to device.

BEHAVIOR
...
```

Table 21
Subschema for Tuner-Device

```
STRUCTURE
  antenna
  dial
  knob
  selector

LAYOUT
  dial on front middle of device
  large knob to right or below dial
  antenna on back top of device

OPERATION
  IF (goal is to select station X)
  THEN (turn knob until dial reads X)

HOW-IT-WORKS
  antenna sends signal to selector controlled
  by knob, selector chooses signal, sends to
  rest of device

BEHAVIOR
...
```

Table 22
Subschema for Audio-Device

```
STRUCTURE
  knob
  speaker
  amplifier

LAYOUT
  speaker on front top center or left
  knob on front or side
  below or right of speaker

OPERATION
  IF (goal is to make sound louder)
  THEN (turn knob clockwise)

  IF (goal is to make sound softer)
  THEN (turn knob counter-clockwise)

HOW-IT-WORKS
  signal goes through knob control to amplifier
  to speaker, and comes out as sound

BEHAVIOR
...
```

The radio schema refers to three subschemas, which are the schemas for generalized line-operated power supplies, audio output stages, and tuners. The schemas in turn can be referred to by other devices, such as stereos or televisions. Each schema consists of the five components of structure, the layout, the operation, the how-it-works information, and the behavior. It is assumed that the schema is represented as a set of propositions, but for ease of reading, the tables use an informal representation. The structure of the device consists of a list of its subdevices, each of which is described by another device schema. The other components of the device schema are expressed in terms of these subdevices, but the information about the subdevices themselves appears only in the schemas for the subdevices. Each subdevice in turn has its own schema; non-schematic "subdevices" would not be represented as subdevices, but as features of the whole device. The hierarchy can be carried as far down as desired; the example shows only enough to illustrate the basic principle.

As shown in the example, the layout component specifies the overall shape of the device, and the location of subdevices and features on the device. Notice that the layout of the subdevices is specified only in terms of the general location of the subdevice; the layout of the features within an individual subdevice is specified in the subdevice schema. This layout information for the whole device and its subdevices is the primary information used to recognize a familiar device, or to recognize the familiar subdevices on an unfamiliar device.

The operation component of a device schema specifies the function of the device and the procedures for using the device. A more precise analysis would rely heavily upon the GOMS model proposed by Card, Moran and Newell (1980, in press) (see Kieras & Polson, Notes 2, 4, for more details). For present purposes, however, the operation component can be considered as consisting simply of a set of procedures for accomplishing each one of the possible goals that can be satisfied with the device. The procedures are specified in production-rule form (see Kieras & Polson, Note 4). Notice that the procedures in the radio schema (Table 19) are expressed in terms of which subdevice to use, so that making the sound louder involves accessing and then executing the proper procedure in the operation component of the appropriate subdevice.

The how-it-works component expresses the relationship between the subdevices represented at that level of the schema. Notice that at any level of the schema, this information may in fact be considerably simpler than many analyses have suggested. This might seem counter-intuitive, because how-it-works knowledge would seem to be extremely complex. However, the above results suggest that in fact, many people have how-it-works knowledge that is relatively consistent and definite, but is extremely limited in detail. In contrast, experts can expand how-it-works statements almost indefinitely, to give, for example, a detailed explanation of the internal structure and principles of the potentiometer

device that is used in a volume control. Naive people must stop merely at the level that a volume control knob controls the signal strength in some way (see Table 22). These phenomena suggest that the how-it-works knowledge is strongly hierarchial. The difference between being naive and expert is mainly that the expert has a much deeper hierarchy; but at the top level, there may be little difference.

In the description task in Experiment 1, the how-it-works knowledge appears to be of such limited quality and content that it plays little role in the interaction between users and devices. This does not mean that such knowledge is not important, but it could mean that such knowledge only plays an important role in certain circumstances. Kieras and Polson (Notes 2 and 4) have proposed some of the ways in which how-it-works knowledge could be important to the operator of the device, but empirical study of this topic is not very advanced. Work currently in progress in our laboratories provides evidence that how-it-works knowledge can be extremely important to the efficient and rapid learning of how to operate a device, but this benefit is not universal. Some aspects of operating a device may not be affected by how-it-works knowledge at all, and in some cases how-it-works knowledge can actually be detrimental to the learner.

The behavior of the device seems to be a necessary component of device knowledge, because, people's natural descriptions of some devices seems to include the fact that the device will behave in a certain way under certain conditions, and this knowledge is expressed independently of user goals or procedures for using the device. However, this information has not appeared very often in the descriptions obtained in the studies described above, which suggests that it is of value only in special occasions. Thus it will not be discussed further.

The proposed schema organization for knowledge of devices appears to be a good way to capture the major phenomena that these studies have uncovered. However, it remains for simulation modelling efforts to determine whether structures such as the radio schema presented above are effective in terms of the actual processes required both to describe devices, and to interact successfully with devices. For example, a strong implication of the proposed schema organization is that the schema hierarchy applies not only to the physical features and structure of a device, but also to the procedures for operating the device. Other empirical work in progress in our laboratory will show whether this implication is correct.

Reference Notes

1. Bond, N. C. & Towne, D. M. Troubleshooting complex equipment in the military services: Research and prospects. Technical Report No. 92, Behavioral Technology Laboratories, University of Southern California, December 1979.

2. Kieras, D. E., & Polson, P. G. An outline of a theory of the user complexity of devices and systems. University of Arizona and University of Colorado, Working Paper No. 1, May 10, 1982.

3. Smith, E. E. & Goodman, L. Understanding instructions: The role of explanatory material. Bolt Beranek and Newman, Inc., Technical Report No. 5088, July 1982.

4. Kieras, D. E., & Polson, P. G. An approach to the formal analysis of user complexity. University of Arizona and University of Colorado, Working Paper No. 2, October 1, 1982.

References

Anderson, J. R. Anderson, J. R. Acquisition of cognitive skill. *Psychological Review*, 1982, *89*, 369-406.

Card, S. K., Moran, T. P., & Newell, A. Computer text editing: An information-processing analysis of a routine cognitive skill. *Cognitive Psychology*, 1980, *12*, 32-74.

Card, S., Moran, T., & Newell, A. *Applied information processing psychology: The human-computer interface*. Hillsdale, New Jersey: Erlbaum, 1982 (in press).

Graesser, A. C. *Prose comprehension beyond the word*. New York: Springer-Verlag, 1981.

Haberlandt, K., Berian, C., & Sandson, J. The episode schema in story processing. *Journal of Verbal Learning and Verbal Behavior*, 1980, *19*, 635-650.

Kintsch, W. On recalling stories. In M. Just & P. Carpenter (Eds.), *Cognitive processes in comprehension*. Hillsdale, N. J.: Lawrence Erlbaum Associates, 1977.

Mandler, J. M. A code in the node: The use of a story schema in retrieval. *Discourse Processes*, 1978, *1*, 1-13.

Navy

1 Robert Ahlers
Code N711
Human Factors Laboratory
NAVTRAEQUIPCEN
Orlando, FL 32813

1 Dr. Meryl S. Baker
Navy Personnel R&D Center
San Diego, CA 92152

1 CDR Robert J. Biersner
Naval Medical R&D Command
National Naval Medical Center
Bethesda, MD 20814

1 Liaison Scientist
Office of Naval Research
Branch Office, London
Box 39
FPO New York, NY 09510

1 Dr. Richard Cantone
Navy Research Laboratory
Code 7510
Washington, DC 20375

1 Chief of Naval Education and Training
Liason Office
Air Force Human Resource Laboratory
Operations Training Division
WILLIAMS AFB, AZ 85224

1 Dr. Stanley Collyer
Office of Naval Technology
800 N. Quincy Street
Arlington, VA 22217

1 CDR Mike Curran
Office of Naval Research
800 N. Quincy St.
Code 270
Arlington, VA 22217

1 Dr. Tom Duffy
Navy Personnel R&D Center
San Diego, CA 92152

1 Dr. Carl E. Englund
Naval Health Research Center
Code 8060 Environmental Physiology Dept
P.O. Box 85122
San Diego, CA 92138

Navy

1 DR. PAT FEDERICO
Code P13
NPRDC
San Diego, CA 92152

1 Dr. John Ford
Navy Personnel R&D Center
San Diego, CA 92152

1 Dr. Jude Franklin
Code 7510
Navy Research Laboratory
Washington, DC 20375

1 Dr. Mike Gaynor
Navy Research Laboratory
Code 7510
Washington, DC 20375

1 Dr. Jim Hollan
Code 304
Navy Personnel R & D Center
San Diego, CA 92152

1 Dr. Ed Hutchins
Navy Personnel R&D Center
San Diego, CA 92152

1 Dr. Norman J. Kerr
Chief of Naval Technical Training
Naval Air Station Memphis (75)
Millington, TN 38054

1 Dr. Peter Kincaid
Training Analysis & Evaluation Group
Dept. of the Navy
Orlando, FL 32813

1 R. W. King
Director, Naval Education and Training
Program
Naval Training Center, Bldg 90
Great Lakes, IL 60088

1 Dr. James Lester
ONR Detachment
495 Summer Street
Boston, MA 02210

1 Dr. Ray Main
Code 14
Navy Personnel R&D Center
San Diego, CA 92152

Navy

1 Dr. William L. Maloy
Principal Civilian Advisor for
Education and Training
Naval Training Command, Code 00A
Pensacola, FL 32508

1 Dr William Montague
NPRDC Code 13
San Diego, CA 92152

1 Naval Ocean R&D Agency
NSTL Station
Attn: LCDR J. D. McKendrick
Code 335
Bay St. Louis, MO 39529

1 Technical Director
Navy Personnel R&D Center
San Diego, CA 92152

6 Commanding Officer
Naval Research Laboratory
Code 2627
Washington, DC 20390

1 Office of Naval Research
Code 433
800 N. Quincy SStreet
Arlington, VA 22217

6 Personnel & Training Research Group
Code 442PT
Office of Naval Research
Arlington, VA 22217

1 Psychologist
ONR Branch Office
1030 East Green Street
Pasadena, CA 91101

1 Office of the Chief of Naval Operations
Research Development & Studies Branch
OP 115
Washington, DC 20350

1 Dr. Gil Ricard
Code N711
NTEC
Orlando, FL 32813

1 Dr. Carl Ross
CNET-PDCD
Building 90
Great Lakes NTC, IL 60088

Navy

1 Dr. Worth Scanland
CNET (N-5)
NAS, Pensacola, FL 32508

1 Dr. Robert G. Smith
Office of Chief of Naval Operations
OP-987H
Washington, DC 20350

1 Dr. Alfred F. Smode, Director
Training Analysis & Evaluation Group
Dept. of the Navy
Orlando, FL 32813

1 Dr. Richard Sorensen
Navy Personnel R&D Center
San Diego, CA 92152

1 Dr. Frederick Steinheiser
CNO - OP115
Navy Annex
Arlington, VA 20370

1 Roger Weissinger-Baylon
Department of Administrative Sciences
Naval Postgraduate School
Monterey, CA 93940

1 Dr. Douglas Wetzel
Code 12
Navy Personnel R&D Center
San Diego, CA 92152

1 Mr John H. Wolfe
Navy Personnel R&D Center
San Diego, CA 92152

Marine Corps

1 H. William Greenup
Education Advisor (E031)
Education Center, MCDEC
Quantico, VA 22134

1 DR. A.L. SLAFKOSKY
SCIENTIFIC ADVISOR (CODE RD-1)
HQ, U.S. MARINE CORPS
WASHINGTON, DC 20380

Army

1 Technical Director
U. S. Army Research Institute for the
Behavioral and Social Sciences
5001 Eisenhower Avenue
Alexandria, VA 22333

1 Mr. James Baker
Army Research Institute
5001 Eisenhower Avenue
Alexandria, VA 22333

1 Dr. Beatrice J. Farr
U. S. Army Research Institute
5001 Eisenhower Avenue
Alexandria, VA 22333

1 Dr. Milton S. Katz
Training Technical Area
U.S. Army Research Institute
5001 Eisenhower Avenue
Alexandria, VA 22333

1 Dr. Marshall Narva
US Army Research Institute for the
Behavioral & Social Sciences
5001 Eisenhower Avenue
Alexandria, VA 22333

1 Dr. Harold F. O'Neil, Jr.
Director, Training Research Lab
Army Research Institute
5001 Eisenhower Avenue
Alexandria, VA 22333

1 Dr. Joseph Psotka
Army Research Institute
5001 Eisenhower Avenue
Alexandria, VA 22333

1 Dr. Robert Sasmor
U. S. Army Research Institute for the
Behavioral and Social Sciences
5001 Eisenhower Avenue
Alexandria, VA 22333

1 Dr. Robert Wisher
Army Research Institute
5001 Eisenhower Avenue
Alexandria, VA 22333

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go
B, TX 76311

Yasatuke

B, AZ 58224

Department of Defense

12 Defense Technical Information Center
Cameron Station, Bldg 5
Alexandria, VA 22314
Attn: TC

1 Military Assistant for Training and
Personnel Technology
Office of the Under Secretary of Defens
for Research & Engineering
Room 3D129, The Pentagon
Washington, DC 20301

1 Major Jack Thorpe
DARPA
1400 Wilson Blvd.
Arlington, VA 22209

Civilian Agencies

1 Dr. Patricia A. Butler
NIE-BRN Bldg, Stop # 7
1200 19th St., NW
Washington, DC 20208

1 Dr. Susan Chipman
Learning and Development
National Institute of Education
1200 19th Street NW
Washington, DC 20208

1 Dr. Andrew R. Molnar
Office of Scientific and Engineering
Personnel and Education
National Science Foundation
Washington, DC 20550

1 Chief, Psychological Reserch Branch
U. S. Coast Guard (G-P-1/2/TP42)
Washington, DC 20593

1 Dr. Frank Withrow
U. S. Office of Education
400 Maryland Ave. SW
Washington, DC 20202

1 Dr. Joseph L. Young, Director
Memory & Cognitive Processes
National Science Foundation
Washington, DC 20550

Private Sector

1 Dr. John R. Anderson
Department of Psychology
Carnegie-Mellon University
Pittsburgh, PA 15213

1 Dr. John Annett
Department of Psychology
University of Warwick
Coventry CV4 7AJ
ENGLAND

1 Dr. Michael Atwood
Bell Laboratories
11900 North Pecos St.
Denver, CO 80234

1 Psychological Research Unit
Dept. of Defense (Army Office)
Campbell Park Offices
Canberra ACT 2600
AUSTRALIA

1 Dr. Alan Baddeley
Medical Research Council
Applied Psychology Unit
15 Chaucer Road
Cambridge CB2 2EF
ENGLAND

1 Dr. Patricia Baggett
Department of Psychology
University of Colorado
Boulder, CO 80309

1 Mr. Avron Barr
Department of Computer Science
Stanford University
Stanford, CA 94305

1 Dr. Menucha Birenbaum
School of Education
Tel Aviv University
Tel Aviv, Ramat Aviv 69978
Israel

1 Dr. John Black
Yale University
Box 11A, Yale Station
New Haven, CT 06520

1 Dr. Lyle Bourne
Department of Psychology
University of Colorado
Boulder, CO 80309

Private Sector

1 Dr. John S. Brown
XEROX Palo Alto Research Center
3333 Coyote Road
Palo Alto, CA 94304

1 Dr. Bruce Buchanan
Department of Computer Science
Stanford University
Stanford, CA 94305

1 Bundministerium der Verteidigung
-Referat P II 4-
Psychological Service
Postfach 1328
D-5300 Bonn 1
F. R. of Germany

1 Dr. C. Victor Bunderson
WICAT Inc.
University Plaza, Suite 10
1160 So. State St.
Orem, UT 84057

1 Dr. Jaime Carbonell
Carnegie-Mellon University
Department of Psychology
Pittsburgh, PA 15213

1 Dr. Pat Carpenter
Department of Psychology
Carnegie-Mellon University
Pittsburgh, PA 15213

1 Dr. William Chase
Department of Psychology
Carnegie Mellon University
Pittsburgh, PA 15213

1 Dr. Micheline Chi
Learning R & D Center
University of Pittsburgh
3939 O'Hara Street
Pittsburgh, PA 15213

1 Dr. William Clancey
Department of Computer Science
Stanford University
Stanford, CA 94306

Private Sector

1 Dr. Michael Cole
University of California
at San Diego
Laboratory of Comparative
Human Cognition - D003A
La Jolla, CA 92093

1 Dr. Allan M. Collins
Bolt Beranek & Newman, Inc.
50 Moulton Street
Cambridge, MA 02138

1 Dr. Lynn A. Cooper
LRDC
University of Pittsburgh
3939 O'Hara Street
Pittsburgh, PA 15213

1 Dr. Kenneth B. Cross
Anacapa Sciences, Inc.
P.O. Drawer Q
Santa Barbara, CA 93102

1 LCOL J. C. Eggenberger
DIRECTORATE OF PERSONNEL APPLIED RESEAR
NATIONAL DEFENCE HQ
101 COLONEL BY DRIVE
OTTAWA, CANADA K1A

1 Dr. Jeffrey Elman
University of California, San Diego
Department of Linguistics
La Jolla, CA 92093

1 Dr. Ed Feigenbaum
Department of Computer Science
Stanford University
Stanford, CA 94305

1 Dr. Paul Feltovich
Department of Medical Education
Southern Illinois University
School of Medicine
P.O. Box 3926
Springfield, IL 62708

1 Professor Reuven Feuerstein
HWCRI Rehov Karmon 6
Bet Hakerem
Jerusalem
Israel

Private Sector

1 Mr. Wallace Feurzeig
Department of Educational Technology
Bolt Beranek & Newman
10 Moulton St.
Cambridge, MA 02238

1 Dr. Victor Fields
Dept. of Psychology
Montgomery College
Rockville, MD 20850

1 Univ. Prof. Dr. Gerhard Fischer
Liebiggasse 5/3
A 1010 Vienna
AUSTRIA

1 Dr. Dexter Fletcher
WICAT Research Institute
1875 S. State St.
Orem, UT 22333

1 Dr. John R. Frederiksen
Bolt Beranek & Newman
50 Moulton Street
Cambridge, MA 02138

1 Dr. Alinda Friedman
Department of Psychology
University of Alberta
Edmonton, Alberta
CANADA T6G 2E9

1 Dr. Michael Genesercth
Department of Computer Science
Stanford University
Stanford, CA 94305

1 Dr. Robert Glaser
Learning Research & Development Center
University of Pittsburgh
3939 O'Hara Street
PITTSBURGH, PA 15260

1 Dr. Marvin D. Glock
217 Stone Hall
Cornell University
Ithaca, NY 14853

1 Dr. Josph Goguen
SRI International
333 Ravenswood Avenue
Menlo Park, CA 94025

Private Sector

1 Dr. Daniel Gopher
Department of Psychology
University of Illinois
Champaign, IL 61820

1 DR. JAMES G. GREENO
LRDC
UNIVERSITY OF PITTSBURGH
3939 O'HARA STREET
PITTSBURGH, PA 15213

1 Dr. Barbara Hayes-Roth
Department of Computer Science
Stanford University
Stanford, CA 95305

1 Dr. Frederick Hayes-Roth
Teknowledge
525 University Ave.
Palo Alto, CA 94301

1 Glenda Greenwald, Ed.
Human Intelligence Newsletter
P. O. Box 1163
Birmingham, MI 48012

1 Dr. Earl Hunt
Dept. of Psychology
University of Washington
Seattle, WA 98105

1 DR. KAY INABA
21116 VANOWEN ST
CANOGA PARK, CA 91303

1 Dr. Walter Kintsch
Department of Psychology
University of Colorado
Boulder, CO 80302

1 Dr. Stephen Kosslyn
Department of Psychology
Brandeis University
Waltham, MA 02254

1 Dr. Pat Langley
Carnegie-Mellon University
Pittsburgh, PA 15213

Private Sector

1 Dr. Marcy Lansman
The L. L. Thurstone Psychometric Laboratory
University of North Carolina
Davie Hall 013A
Chapel Hill, NC 27514

1 Dr. Jill Larkin
Department of Psychology
Carnegie Mellon University
Pittsburgh, PA 15213

1 Dr. Alan Lesgold
Learning R&D Center
University of Pittsburgh
3939 O'Hara Street
Pittsburgh, PA 15260

1 Dr. Jim Levin
University of California at San Diego
Laboratory fof Comparative Human Cognition - D003A
La Jolla, CA 92093

1 Dr. Michael Levine
Department of Educational Psychology
210 Education Bldg.
University of Illinois
Champaign, IL 61801

1 Dr. Jay McClelland
Department of Psychology
MIT
Cambridge, MA 02139

1 Dr. James R. Miller
Texas Instruments, Inc.
Central Research Laboratory
P. O. Box 226015, MS238
Dallas, TX 75266

1 Dr. Mark Miller
Computer Thought Corporation
1721 West Plane Parkway
Plano, TX 75075

1 Dr. Allen Munro
Behavioral Technology Laboratories
1845 Elena Ave., Fourth Floor
Redondo Beach, CA 90277

Private Sector

1 Dr. Donald A Norman
Cognitive Science, C-015
Univ. of California, San Diego
La Jolla, CA 92093

1 Committee on Human Factors
JH 811
2101 Constitution Ave. NW
Washington, DC 20418

1 Dr. Jesse Orlansky
Institute for Defense Analyses
1801 N. Beauregard St.
Alexandria, VA 22311

1 Dr. Seymour A. Papert
Massachusetts Institute of Technology
Artificial Intelligence Lab
545 Technology Square
Cambridge, MA 02139

1 Dr. Nancy Pennington
University of Chicago
5801 S. Ellis Avenue
Chicago, IL 60637

1 Mr. L. Petrullo
2431 N. Edgewood Street
ARLINGTON, VA 22207

1 DR. PETER POLSON
DEPT. OF PSYCHOLOGY
UNIVERSITY OF COLORADO
BOULDER, CO 80309

1 Dr. Fred Reif
Physics Department
University of California
Berkeley, CA 94720

1 Dr. Lauren Resnick
LRDC
University of Pittsburgh
3939 O'Hara Street
Pittsburgh, PA 1521

1 Dr. Jeff Richardson
Denver Research Institute
University of Denver
Denver, CO 80208

Private Sector

1 Mary S. Riley
Program in Cognitive Science
Center for Human Information Processing
University of California, San Diego
La Jolla, CA 92093

1 Dr. Andrew M. Rose
American Institutes for Research
1055 Thomas Jefferson St. NW
Washington, DC 20007

1 Dr. Ernst Z. Rothkopf
Bell Laboratories
Murray Hill, NJ 07974

1 Dr. William B. Rouse
Georgia Institute of Technology
School of Industrial & Systems
Engineering
Atlanta, GA 30332

1 Dr. David Rumelhart
Center for Human Information Processing
Univ. of California, San Diego
La Jolla, CA 92093

1 Dr. Michael J. Samet
Perceptronics, Inc
6271 Variel Avenue
Woodland Hills, CA 91364

1 Dr. Arthur Samuel
Yale University
Department of Psychology
Box 11A, Yale Station
New Haven, CT 06520

1 Dr. Roger Schank
Yale University
Department of Computer Science
P.O. Box 2158
New Haven, CT 06520

1 Dr. Alan Schoenfeld
Mathematics and Education
The University of Rochester
Rochester, NY 14627

1 DR. ROBERT J. SEIDEL
INSTRUCTIONAL TECHNOLOGY GROUP
HUMRRO
300 N. WASHINGTON ST.
ALEXANDRIA, VA 22314

Private Sector

1 Mr. Colin Sheppard
Applied Psychology Unit
Admiralty Marine Technology Est.
Teddington, Middlesex
United Kingdom

1 Dr. H. Wallace Sinaiko
Program Director
Manpower Research and Advisory Services
Smithsonian Institution
801 North Pitt Street
Alexandria, VA 22314

1 Dr. Edward E. Smith
Bolt Beranek & Newman, Inc.
50 Moulton Street
Cambridge, MA 02138

1 Dr. Richard Snow
School of Education
Stanford University
Stanford, CA 94305

1 Dr. Eliott Soloway
Yale University
Department of Computer Science
P.O. Box 2158
New Haven, CT 06520

1 Dr. Kathryn T. Spoehr
Psychology Department
Brown University
Providence, RI 02912

1 Dr. Robert Sternberg
Dept. of Psychology
Yale University
Box 11A, Yale Station
New Haven, CT 06520

1 Dr. Albert Stevens
Bolt Beranek & Newman, Inc.
10 Moulton St.
Cambridge, MA 02238

1 David E. Stone, Ph.D.
Hazeltine Corporation
7680 Old Springhouse Road
McLean, VA 22102

Private Sector

1 DR. PATRICK SUPPES
INSTITUTE FOR MATHEMATICAL STUDIES IN
THE SOCIAL SCIENCES
STANFORD UNIVERSITY
STANFORD, CA 94305

1 Dr. Kikumi Tatsuoka
Computer Based Education Research Lab
252 Engineering Research Laboratory
Urbana, IL 61801

1 Dr. Perry W. Thorndyke
Perceptronics, Inc.
245 Park Lane
Atherton, CA 94025

1 Dr. Douglas Towne
Univ. of So. California
Behavioral Technology Labs
1845 S. Elena Ave.
Redondo Beach, CA 90277

1 Dr. Kurt Van Lehn
Xerox PARC
3333 Coyote Hill Road
Palo Alto, CA 94304

1 DR. GERSHON WELTMAN
PERCEPTRONICS INC.
6271 VARIEL AVE.
WOODLAND HILLS, CA 91367

1 Dr. Keith T. Wescourt
Perceptronics, Inc.
545 Middlefield Road, Suite 140
Menlo Park, CA 94025

1 William B. Whitten
Bell Laboratories
2D-610
Holmdel, NJ 07733

1 Dr. Mike Williams
Xerox PARC
3333 Coyote Hill Road
Palo Alto, CA 94304